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Jawaharlal Nehru

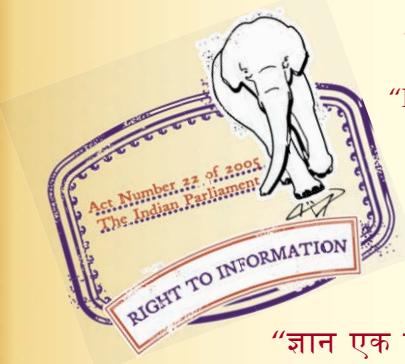
“Step Out From the Old to the New”

IS 398-4 (1994): Aluminium conductors for overhead transmission purposes, Part 4: Aluminium alloy stranded conductors (aluminium magnesium silicon type) [ETD 37: Conductors and Accessories for Overhead Lines]

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Bhartṛhari—Nītiśatakam

“Knowledge is such a treasure which cannot be stolen”





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भारतीय मानक

शिरोपरि प्रेषण कार्यों के लिए ऐल्युमिनियम के चालक

भाग 4 ऐल्युमिनियम मिथधातु लड़दार चालक (ऐल्युमिनियम-  
मैग्नीशियम-सिलिकॉन प्रकार) — विशिष्टि

( तीसरा पुनरीक्षण )

*Indian Standard*

ALUMINIUM CONDUCTORS FOR  
OVERHEAD TRANSMISSION PURPOSES

PART 4 ALUMINIUM ALLOY STRANDED CONDUCTORS  
(ALUMINIUM-MAGNESIUM-SILICON TYPE) — SPECIFICATION

( *Third Revision* )

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BUREAU OF INDIAN STANDARDS  
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG  
NEW DELHI 110002

**AMENDMENT NO. 1 MAY 2000**  
**TO**  
**IS 398 ( PART 4 ) 1994 ALUMINIUM CONDUCTORS**  
**FOR OVERHEAD TRANSMISSION PURPOSES**

**PART 4 ALUMINIUM ALLOY STRANDED CONDUCTORS  
(ALUMINIUM-MAGNESIUM-SILICON TYPE) — SPECIFICATION**

*( Third Revision )*

*( Foreword, last two sentences of para 4 ) — Substitute the following for the existing:*

*'The maximum resistivity of 0.032 8 ohm.mm<sup>2</sup>/m at 20°C has been adopted for arriving at the calculated resistance of conductor.'*

*( Page 1, clause 4.1 ) — Substitute the following for the existing:*

**'4.1 Resistivity'**

*For the purpose of this standard, the maximum value of resistivity of any single aluminium alloy wire which shall be used for calculation is 0.032 8 ohm.mm<sup>2</sup>/m at 20°C.'*

*( Page 2, Table 1, col 5 ) — Substitute '28.41' and '29.19' for '26.41' and '21.19' respectively.*

*( Page 3, Table 2, col 6, Sl No. 8 ) — Substitute '0.229 8' for '0.229 0'.*

*( Page 3, Table 2, col 6, Sl No. 14 ) — Substitute '0.085 5' for '0.082 9'.*

*( Page 3, clause 8.1 ) — Substitute the following for the existing:*

**'8.1 Conductors Containing Up to Seven Wires'**

*'There shall be no joints in any wire of a stranded conductor containing up to 7 wires except, those made in the base rod or wire before final drawing.'*

*( Page 5, Annex A, col 2, title ) — Substitute 'kg/cm<sup>2</sup>' for 'GN/m<sup>2</sup>'.*

*( Page 6, Annex A ) — Delete the table of 'Breakup details of revised AAC Conductor.'*

**( ETD 37 )**

## FOREWORD

This Indian Standard (Part 4) (Third Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Conductors and Accessories for Overhead Lines Sectional Committee had been approved by the Electrotechnical Division Council.

This part of the standard was originally published in 1953, the first revision was then, brought out in 1961 and the second revision in 1979. Third revision has been undertaken with a view to effecting the following modifications:

- a) to line up with the International Standards.
- b) to further rationalize the sizes of aluminium alloy stranded conductors (aluminium-magnesium-silicon type) to conform to the requirements of Indian power utilities.

This standard is issued in different parts covering different types of conductors. This part dealing with aluminium alloy stranded conductors forms Part 4 of the series. The other parts in the series are given below:

- Part 1 Aluminium stranded conductors
- Part 2 Aluminium conductors, galvanized steel—reinforced
- Part 3 Aluminium conductors, aluminized steel—reinforced
- Part 5 Aluminium conductors, galvanized steel—reinforced for extra high voltage

In this revision the conductor and the alloy wire properties have been rationalised to keep in tune and to ensure compatibility with other Indian Standards for conductors. The minimum breaking load of alloy wires before and after stranding have been introduced. The standard resistivity figure of  $0.032\text{5 ohm}.\text{mm}^2/\text{m}$  at  $20^\circ\text{C}$  has been adopted for arriving at the calculated resistance of the conductors. However, individual wires with a maximum resistivity up to  $0.032\text{8 ohm}.\text{mm}^2/\text{m}$  at  $20^\circ\text{C}$  will be permitted.

In the preparation of this standard, assistance has been derived from the following:

IEC Pub 208 (1966) Aluminium Alloy Stranded Conductors, International Electrotechnical Commission

BS 3242 : 1970 Specification for Aluminium Alloy Stranded Conductors for Overhead Power Transmission. British Standards Institution

ASTM—B 398M-86 Specification for Aluminium Alloy 6201 T81 Wire for Electrical Purposes

ASTM—B 399M-86 Standard Specification for Concentric Layer — Stranded Aluminium Alloy 6201 -T81 Conductors

The values of modulus of elasticity and co-efficient of linear expansion are given in Annex A for information.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Indian Standard*

# ALUMINIUM CONDUCTORS FOR OVERHEAD TRANSMISSION PURPOSES

## PART 4 ALUMINIUM ALLOY STRANDED CONDUCTORS (ALUMINIUM-MAGNESIUM-SILICON TYPE) — SPECIFICATION

*( Third Revision )*

### **1 SCOPE**

**1.1** This standard (Part 4) covers the requirements and tests for aluminium alloy stranded conductors of the aluminium-magnesium-silicon type for overhead power transmission purposes.

### **2 REFERENCES**

**2.1** The following Indian Standards are necessary adjuncts to this standard:

<i>IS No.</i>	<i>Title</i>
1885 (Part 32) : 1971	Electrotechnical vocabulary; Part 32 Cables, conductors and accessories for electricity supply
9997 : 1981	Aluminium alloy redraw rods for electrical purposes ( <i>first revision</i> )

### **3 TERMINOLOGY**

**3.1** For the purpose of this standard, the following definitions in addition to those given in IS 1885 (Part 32) : 1971 shall apply.

#### **3.1.1 Stranded Conductor**

Conductor consisting of three or more aluminium wires of the same nominal diameter twisted together in concentric layers. When the conductor consists of more than one layer, successive layers are twisted in opposite directions.

#### **3.1.2 Diameter**

The mean of two measurements at right angles taken at the same cross-section.

#### **3.1.3 Direction of Lay**

The direction of lay is defined as right-hand or left-hand. With right-hand lay, the wires conform to the direction of the central part of the letter Z, when the conductor is held vertically. With left-hand lay, the wires conform to the direction of the central part of the letter S when the conductor is held vertically.

#### **3.1.4 Lay Ratio**

Ratio of the axial length of one complete turn of the helix formed by an individual wire in a stranded conductor to the external diameter of the helix.

#### **3.1.5 Heat-Treatment Batch**

One furnace load of material heat treated at the same time, at the same temperature and for the same length of time.

### **4 PHYSICAL CONSTANTS FOR ALUMINIUM ALLOY WIRES**

#### **4.1 Resistivity**

For the purposes of this standard, the standard value of resistivity of aluminium alloy wire which shall be used for calculation is to be taken as  $0.032\ 5\ \text{ohm mm}^2/\text{m}$  at  $20^\circ\text{C}$ . The maximum value of resistivity of any single wire shall not, however, exceed  $0.032\ 8\ \text{ohm mm}^2/\text{m}$  at  $20^\circ\text{C}$ .

#### **4.2 Density**

At a temperature of  $20^\circ\text{C}$ , the density of aluminium alloy wire is to be taken as  $2.70\ \text{kg}/\text{dm}^3$ .

#### **4.3 Co-efficient of Linear Expansion**

The co-efficient of linear expansion of aluminium alloy wire is to be taken as  $23 \times 10^{-6}/^\circ\text{C}$ .

#### **4.4 Constant-Mass Temperature Co-efficient ( $\alpha$ )**

At a temperature of  $20^\circ\text{C}$ , the constant-mass temperature co-efficient of resistance of aluminium alloy wires, measured between two potential points rigidly fixed to the wire, is taken as  $0.003\ 60/^\circ\text{C}$ .

### **5 MATERIAL**

**5.1** The wires shall be of heat treated aluminium, magnesium silicon alloy having a composition appropriate to the mechanical and electrical properties specified in Table 1.

## 6 FREEDOM FROM DEFECTS

**6.1** The wires shall be smooth and free from all imperfections not consistent with good commercial practice, for example, spills, splits and scratches.

## 7 STANDARD SIZES

### 7.1 Wires

#### 7.1.1 Nominal Sizes

The aluminium alloy wires for standard constructions covered by this standard shall have the diameters specified in Table 1.

#### 7.1.2 Tolerances on Nominal Sizes

A tolerance of  $\pm 1$  percent shall be permitted on the nominal diameter specified in Table 1.

### 7.2 Stranded Conductors

#### 7.2.1 Sizes

The sizes of stranded aluminium alloy conductors shall be as given in Table 2.

**7.2.2** The resistance of stranded conductors shall be in accordance with Table 2. The masses (excluding the mass of grease, if applied) are given in Table 2 for information.

**Table 1 Aluminium Alloy Wires Used in the Construction of  
Stranded Aluminium Alloy Conductors  
( Clauses 5.1, 7.1.1, 7.1.2, 12.4 and B-3.1 )**

Nom	Diameter			Cross Sectional Area of Nominal Diameter Wire	Mass	Minimum Breaking Load		Resistance at 20°C Max
	Min	Nom	Max			Before Stranding	After Stranding	
mm	mm	mm	mm	mm <sup>2</sup>	kg/km	kN	kN	ohms/km
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
2.00	1.98	2.02	3.142	8.482	13.25	0.97	0.92	10.653
2.50	2.47	2.53	4.909	17.71	1.52	1.44	1.39	6.845
2.89	2.86	2.92	6.560	21.04	2.03	1.93	1.86	5.106
3.15	3.12	3.18	7.793	23.23	2.41	2.29	2.18	4.290
3.31	3.28	3.34	8.605	24.51	2.66	2.53	2.42	3.882
3.40	3.37	3.43	9.079	25.24	2.80	2.66	2.54	3.677
3.45	3.42	3.48	9.348	26.72	2.89	2.75	2.63	3.571
3.55	3.51	3.59	9.898	26.72	3.06	2.91	2.78	3.390
3.66	3.62	3.70	10.52	26.41	3.25	3.09	2.96	3.187
3.71	3.67	3.75	10.81	21.19	3.34	3.17	3.04	3.101
3.81	3.77	3.85	11.40	30.78	3.52	3.34	3.21	2.938
3.94	3.90	3.98	12.19	32.92	3.77	3.58	3.45	2.746
4.00	3.96	4.04	12.57	33.93	3.88	3.69	3.56	2.663
4.26	4.22	4.30	14.25	38.48	4.40	4.18	3.95	2.345

#### NOTES

- 1 Maximum resistance values given in col 8 have been calculated from the maximum values of the resistivity and the cross sectional area based on the minimum diameter.
- 2 The minimum breaking load is calculated on nominal diameter at ultimate tensile strength of  $31.5\text{kg/mm}^2$  for a wire before stranding and 95 percent of that after stranding.

**Table 2 Aluminium Alloy Stranded Conductors**  
*(Clauses 7.2.1 and 7.2.2; and Table 1)*

Sl. No.	Actual Area	Stranding and Wire Dia	Approx Overall Dia	Approx Mass	Calculated Maximum Resistance at 20°C	Approx Calculated Breaking Load
	mm <sup>2</sup>	mm	mm	kg/km	ohms/km	kN
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	15	3/2.50	5.39	40.15	2.304 0	4.33
2.	22	7/2.00	6.00	60.16	1.541 0	6.45
3.	34	7/2.50	7.50	94.00	0.990 0	10.11
4.	55	7/3.15	9.45	149.20	0.621 0	16.03
5.	80	7/3.81	11.43	218.26	0.425 0	23.41
6.	100	7/4.26	12.78	272.86	0.339 0	29.26
7.	125	19/2.89	14.45	342.51	0.273 5	36.64
8.	148	19/3.15	15.75	406.91	0.229 0	43.50
9.	173	19/3.40	17.00	474.02	0.196 9	50.54
10.	200	19/3.66	18.30	549.40	0.171 0	58.66
11.	232	19/3.94	19.70	636.67	0.147 1	68.05
12.	288	37/3.15	22.05	794.05	0.118 2	84.71
13.	346	37/3.45	24.15	952.56	0.098 4	101.58
14.	400	37/3.71	25.97	1 101.63	0.082 9	117.40
15.	465	37/4.00	28.00	1 280.50	0.073 4	136.38
16.	525	61/3.31	29.79	1 448.39	0.065 1	146.03
17.	570	61/3.45	31.05	1 573.71	0.059 8	158.66
18.	604	61/3.55	31.95	1 666.00	0.056 8	167.99
19.	642	61/3.66	32.94	1 771.36	0.053 4	178.43
20.	695	61/3.81	34.29	1 919.13	0.049 2	193.25
21.	767	61/4.00	36.00	2 115.54	0.044 6	213.01

**NOTES**

- 1 For the basis of calculation of this table, see Annex B.
- 2 The actual area of a stranded conductor has been taken as the sum of the cross-sectional areas of the individual wires of nominal diameter.
- 3 Maximum resistance values of stranded conductor have been calculated on the basis of maximum resistivity and the cross sectional area based on the minimum diameter.

**8 JOINTS IN WIRES****8.1 Conductors Containing Seven Wires**

There shall be no joint in any wire of a stranded conductor containing seven wires, except those made in the base rod or wire before final drawing.

**8.2 Conductors Containing More Than Seven Wires**

In stranded conductors containing more than seven wires, joints in individual wires are permitted in any layer except the outermost layer (in addition to those made in the base rod or wire before final drawing) but no two such joints shall be less than

15 m apart in the complete stranded conductor. Such joints shall be made by resistance or cold-pressure butt welding. They are not required to fulfil the mechanical requirements for unjointed wires. Joints made by resistance butt welding subsequent to welding, be annealed over a distance of at least 200 mm on each side of the joint.

**9 STRANDING**

**9.1** The wire used in the construction of a stranded conductor shall, before and after stranding, satisfy all the relevant requirements of this standard.

**9.2** The lay ratio of the different layers shall be within the limits given in Table 3.

**Table 3 Lay Ratios for Aluminium Alloy Stranded Conductors  
(Clauses 9.2 and B-2.3)**

Number of Wires in Conductor	Lay Ratios							
	36 Wire Layer		12 Wire Layer		18 Wire Layer		24 Wire Layer	
	Min	Max	Min	Max	Min	Max	Min	Max
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
3	10	14	—	—	—	—	—	—
7	10	14	—	—	—	—	—	—
19	10	16	10	14	—	—	—	—
37	10	17	10	16	10	14	—	—
61	10	17	10	16	10	15	10	14

NOTE— For the purpose of calculation, the mean lay ratio shall be taken as the arithmetic mean of the relevant minimum and maximum values given in this table.

**9.3** In all constructions, the successive layers shall have opposite directions of lay, the outermost layer being right-handed. The wires in each layer shall be evenly and closely stranded.

**9.4** In aluminium alloy stranded conductors having multiple layers of wires, the lay ratio of any layer shall be not greater than the lay ratio of the layer immediately beneath it.

## 10 LENGTHS AND VARIATIONS IN LENGTHS

**10.1** Unless otherwise agreed between the purchaser and the manufacturer, stranded aluminium alloy conductors shall be supplied in the manufacturer's usual production lengths and with a permitted variation of  $\pm 5$  percent in the length of any one conductor length.

## 10.2 Random Lengths

Unless otherwise agreed between the purchaser and the manufacturer, it shall be permissible to supply not more than 10 percent of the lengths on any one order in random lengths; none of them shall be shorter than one-third of the nominal length.

## 11 PACKING AND MARKING

**11.1** The conductor shall be wound on reels or drums and marked with the following:

- Indication of source of manufacture,
- Size of conductor,
- Length of conductor, and
- Net and gross mass of conductor.

**11.1.1** The conductor may also be marked with Standard Mark.

**11.1.1.1** The use of Standard Mark is governed by the provisions of Bureau of Indian Standards Act, 1986 and the Rules and Regulations made thereunder. The details of conditions under where the licence for the use of standard mark may be granted

to the manufacturers or producers may be obtained from the Bureau of Indian Standards.

## 12 TESTS

### 12.1 Selection of Test Samples

**12.1.1** Samples for the tests specified in 12.2, 12.3 and 12.4 shall be taken by the manufacturer before stranding, from not less than 10 percent of the individual lengths of aluminium alloy wire included in any one final heat-treatment batch and which will be included in any one consignment of stranded conductors.

### 12.1.2 Alternatively

If desired by the purchaser at the time of placing an order that the tests be made in the presence of his representative, samples of wire shall be taken from length of stranded conductors. Samples shall then be obtained by cutting 1.2 metres from the outer end of the finished conductor from not more than 10 percent of the finished reels or drums.

**12.1.3** Tests for electrical and mechanical properties of aluminium alloy wire shall ordinarily be made before stranding because wires unlaid from conductors may have different physical properties from those of the wire prior to stranding because of the deformation brought about by stranding and by straightening for test.

**12.1.4** Spools offered for inspection shall be divided into equal lots, the number of lots being equal to the number of samples to be selected, a fraction of a lot being counted as a complete lot. One sample spool shall be selected at random from each lot.

### 12.2 Breaking Load Test

**12.2.1** The breaking load of one specimen, cut from each of the sample taken under 12.1.1 or 12.1.2 shall be determined by means of suitable tensile testing machine. The load shall be applied

gradually and the rate of separation of the jaws of the testing machine shall be not less than 25 mm/min and not greater than 100 mm/min.

### 12.3 Elongation Test

The elongation of one specimen cut from each of the samples taken under 12.1.1 or 12.1.2 shall be determined as follows.

**12.3.1** The specimen shall be straightened by hand and an original gauge length of 200 mm shall be marked on the wire. A tensile load shall be applied as described in 11.2 above and the elongation shall be measured after the fractured ends have been fitted together. If the fracture occurs outside the gauge marks, or within 25 mm of either mark, and the required elongation is not obtained, the test shall be disregarded and another test should be made.

When tested before and after stranding, the elongation shall be not less than 4 percent on a gauge length of 200 mm.

### 12.4 Resistance Test

The electrical resistance of one specimen cut from each of the samples taken under 12.1.1 or 12.1.2 shall be measured at ambient temperature. The measured resistance shall be corrected to the value at 20°C by means of the formula:

$$R_{20} = R_T \frac{1}{1 + \alpha(T-20)}$$

where

$R_{20}$  = resistance corrected at 20°C,  
 $R_T$  = resistance measured at T°C,  
 $\alpha$  = constant-mass temperature co-efficient of resistance, 0.003 6, and  
 $T$  = ambient temperature during measurement.

The resistance corrected at 20°C shall be not more than the maximum values specified in Table 1.

### 13 REJECTION AND RETESTS

**13.1** Should any one of the test pieces first selected fail to the requirements of the tests, two further samples from the same batch shall be selected for testing, one of which shall be from the length from which the original test sample was taken unless that length has been withdrawn by the supplier.

**13.2** Should the test pieces from both these additional samples satisfy the requirements of the tests, the batch represented by these samples shall be deemed to comply with the standard. Should the test pieces from either of the two additional samples fail, the batch represented shall be deemed not to comply with the standard.

## ANNEX A

### (Foreword)

### MODULUS OF ELASTICITY AND COEFFICIENT OF LINEAR EXPANSION

No. of Wires	Final Modulus of Elasticity GN/m <sup>2</sup>	Coefficient of Linear Expansion/ $^{\circ}\text{C}$
3	$0.650\ 0 \times 10^6\ \text{kg/cm}^2$	$23.0 \times 10^{-6}$
7	$0.632\ 4 \times 10^6\ \text{kg/cm}^2$	$23.0 \times 10^{-6}$
19	$0.612 \times 10^6\ \text{kg/cm}^2$	$23.0 \times 10^{-6}$
37	$0.581\ 4 \times 10^6\ \text{kg/cm}^2$	$23.0 \times 10^{-6}$
61	$0.550\ 8 \times 10^6\ \text{kg/cm}^2$	$23.0 \times 10^{-6}$

NOTE — These values are given for information only.

## Break Up Details of Revised AAAC Conductor

Sl. No.	For Electro-Mechanical Equivalence to Exist- ing ACSR Conductors		For Uprating Existing ACSR Conductors		For Bridging Gaps	
	Size in mm <sup>2</sup>	Eqt. ACSR	Size in mm <sup>2</sup>	Existing ACSR Conductor	Size in mm <sup>2</sup>	
1.	20	20	125/150	100	15-Street Lighting/ Telecommunication 700-800 kV/ Substation bus-bars	
2.	35	30			765-800 kV/Substation bus-bars, equivalent to ACSR	
3.	55	50	290/345	200		
4.	100	100	525	420		
5.	175	150	640/695	560		
6.	230	200				
7.	400	400				
8.	465	420				
9.	570	520				
10.	605	560				

## ANNEX B

(Table 2)

## NOTES ON THE CALCULATION OF TABLE 2

**B-1 INCREASE IN LENGTH DUE TO  
STRANDING**

**B-1.1** When straightened out, each wire in any particular layer of a stranded conductor, except the central wire, is longer than the stranded conductor by an amount depending on the lay ratio of that layer.

**B-2 RESISTANCE AND MASS OF  
CONDUCTOR**

**B-2.1** The resistance of any length of a stranded conductor is the resistance of the same length of any one wire multiplied by a constant as set out in Table 4.

**B-2.2** The mass of each wire in any particular layer of stranded conductor, except the central wire, will be greater than that of an equal length of straight wire by an amount depending on the lay ratio of that layer (see B-1.1). The total mass of any length of an aluminium stranded conductor is, therefore, obtained by multiplying the mass of an equal length of straight wire by an appropriate constant, as set out in Table 4.

**B-2.3** In calculating the stranding constants in Table 4, the mean lay ratio, that is the arithmetic mean of the relevant minimum and maximum values in Table 3, has been assumed for each layer.

**B-3 CALCULATED BREAKING LOAD OF  
CONDUCTOR**

**B-3.1** The strength of conductor in terms of individual component wires shall be taken as follows:

- For a conductor containing not more than 37 wires, 95 percent of the sum of strength of the individual wires calculated from the values of the minimum breaking load given in col 6 of Table 1.
- For a conductor containing more than 37 wires, 90 percent of the sum of strengths of the individual wire calculated from the values of the minimum breaking load given in col 6 of Table 1.

Table 4 Stranding Constants  
(Clauses B-2.1, B-2.2 and B-2.3; and Table 1 )

Number of Wires in Conductor	Stranding Constants	
	Mass	Electrical Resistance
(1)	(2)	(3)
3	3.029	0.336 6
7	7.091	0.144 7
19	19.34	0.053 57
37	37.74	0.027 57
61	62.35	0.016 76

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### **Amendments Issued Since Publication**

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{ 832 92 95, 832 78 58  
832 78 91, 832 78 92

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